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ABSTRACT

The purpose of this paper is to review evaluation theories and techniques in both the medical and educational fields and to propose an evaluation theory to explain the condition variables, the method variables, and the outcome variables of student assessment in a problem-based learning (PBL) approach. The PBL definition and process are presented, and the following goals of PBL are summarized: metacognition; self-directed learning; critical thinking and problem solving skills; knowledge acquisition, retention, and use; collaborative learning; and higher motivation and positive attitude. A categorization scheme of assessment is presented that includes a wide range of evaluation techniques and tools to assess students' behaviors and products in a PBL approach. Process-oriented and outcome-oriented approaches are used to classify the assessment methods. Process-oriented evaluation methods include: tutor, peer ratings; self-evaluation; unobtrusive measure; oral examination; observation of a patient interview and examination; patient problem simulations; review of case record; authentic assessment; and performance assessment. Outcome-oriented evaluation methods include: review of case record; student-judged evaluation; multiple-choice examinations; short-answer or word-completion examinations; essay examinations; patient problem simulations; and portfolio assessment. (Contains 25 references.) (MES)

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Evaluation Theory in Problem-Based Learning Approach

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Abstract

Student assessment refers to the evaluation of students' performance using appropriate methods. The impact of student assessment on learning is emphasized by many educators. However, not many articles discuss the methodology of assessment in a problem-based learning approach. The purpose of this paper is to review evaluation theories and techniques in both the medical and educational fields and to propose an evaluation theory to explain the condition variables, the method variables, and the outcome variables of student assessment in a problem-based learning approach. A categorization scheme of assessment will be presented, which includes a wide range of evaluation techniques and tools to assess students' behaviors and products in a problem-based learning approach.

Introduction

Evaluation in problem-based learning (PBL) includes student assessment and program evaluation. Student assessment refers to the evaluation of students' performance using appropriate methods. The impact of student assessment on learning is emphasized by many educators. However, not many scholars discuss how professors evaluate students. Swanson, Case, and van der Vleuten (1991) note that "despite recognition of the importance of assessment among problem-based learning advocates, there is little agreement on methodologies for assessment." The purpose of this study is to review evaluation theories and techniques in both the medical and educational fields and to propose an evaluation theory to explain the condition variables, the method variables, and the outcome variables of student assessment in a problem-based learning approach. A categorization scheme of assessment will be presented, which includes a wide range of evaluation techniques and tools. In this paper, PBL will be briefly discussed in respect to its definition, process, and intended learning outcomes. Secondly, the theoretical basis of PBL evaluation and the categorization scheme of assessment will be presented.

Problem-based learning

Problem-based learning is a commonly used instructional approach in today's medical schools in the United States. The advantages of PBL make it a superior way compared to the teacher-centered lecture approach. The traditional approach was criticized as placing too much emphasis on memorization but not enough emphasis on developing thinking skills. Students are passive learners and fail to transfer their knowledge to different environments. Whereas, PBL fosters students' multiple skills and allows them to acquire knowledge in the process of solving problems. In this section, the learning process and intended outcomes of PBL will be reviewed.

The PBL definition and process

Problem based learning is defined as "the learning that results from the process of working toward the understanding or resolution of a problem" (West, 1992). In a PBL approach the students are active learners. Several authors (Gallagher, 1997; Savery and Duffy, 1996; West, 1992) describe students' tasks in the learning process. According to their description, all students in a small group work on the same problem presented by the teacher. They need to internalize and reason through the problem to identify the learning issues and define the objectives. As tasks and work schedule are assigned to each group member, they start to identify resources to gather information related to the learning issues. Each member brings back and reports his findings for the whole group to analyze the data or to shape their learning issues in order to identify the solutions. Once students synthesize and summarize findings into solutions, they need to conduct an assessment to see if all the objectives have been satisfied and to evaluate their performance. Finally, they receive feedback from the facilitator. To summarize, the tasks students need to perform are:

- Defining problem and identifying the issues
- Framing learning objectives
- Determining work schedule
- Gathering and analyzing data
- Presenting and discussing learning findings related to learning issues
- Synthesizing and summarizing findings into solutions
- Justifying solution and evaluating performance

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Goals of PBL

PBL approach is intended to foster student's skills in facing their future learning and profession. Students' goals of learning include metacognition skills, self-directed learning skills, critical thinking and problem solving skills, learners' knowledge acquisition and use, collaborative learning, as well as their higher motivation and positive attitude. In this section, these goals will be shortly discussed.

Metacognition

According to Barrow (1988), metacognition is thinking about thinking. It's the "executive function in thinking: pondering, deliberating, or reflecting on the problem or situation; reviewing what is known and remembered about the kind of problem confronted; creating hypotheses, making decisions about what observations, questions or probes need to be made; questioning the meaning of new information obtained from inquiry; reviewing what has been learned, what it all may mean and what needs to be done next, etc." An expert problem solver can monitor and control their thinking process to attain their best effectiveness.

Self-directed learning

Since knowledge changes rapidly, PBL approach fosters students' self-directed learning skills so that they will automatically continue their own learning for the rest of their lives (Barrow, 1988). PBL allows students to determine what and how to learn on their own in order to ensure their lifelong learning skills and the ability to be effective and independent learners.

Critical thinking skills and problem solving skills

According to Scheiman and Dell (1989), the problem solving process has been called the clinical reasoning process, which refers to "the cognitive process that is necessary to evaluate and manage a patient's problem." In a PBL approach, students need to identify learning issues, develop strategies, locate information relevant to the issue, and evaluate their solution. This entire learning process helps to develop their problem solving and thinking skills (Savery and Duffy, 1996).

Knowledge acquisition, retention, and use

Wilderson and Feletti (1989) claim that two types of knowledge learners acquire when they solve problems are concept and procedural knowledge. In other words, they are knowledge of concepts, principles and facts, as well as the procedure for how to use them. Hmelo and Ferrari (1997) note one goal of PBL as the construction of an extensive and flexible knowledge base. They summarize several studies and conclude that students in PBL learn at least as much social-studies and life-science content as students in a traditional classroom.

Collaborative learning

PBL facilitates the development of effective collaborative learning practices. Students working in small groups compare their thoughts to those of others. They develop individual perspectives and recognize those of others. PBL not only provides students with the opportunity to communicate in a social setting but also enables them to cooperatively work with others to understand different views.

Higher motivation and positive attitude

In a PBL program, students are active learners and have the ownership for their learning. Therefore, they express a more positive attitude and higher motivation in learning than do students in traditional programs.

Need for an evaluation theory

As I reviewed the evaluation theories and techniques in several articles, I found that some authors use different terminology to refer to the same concepts. In addition, there are controversies in their view of different evaluation techniques and tools. Some of them present the assessment methods that are only applied in medical schools, while others describe their experience of using PBL in other fields. I synthesized those evaluation techniques and identified gaps or conflicts between them. As a result, I find it is necessary to generate an evaluation theory for a problem-based learning approach that synthesizes these theories and techniques in a more holistic way and provides comprehensive evaluation techniques, assessment circumstance, as well as outcomes to which educators and future researchers can refer. In the following sections I present my theory of student assessment, which is underpinned by several assessment theories and studies, as well as by my personal experience.

Theoretical basis and the philosophy of assessment

PBL was first implemented in medical education in the early 1970's and gradually was applied to other fields. Norman and Schmidt (1992) note that PBL is a learning method based on the rationalist tradition and is strongly influenced by cognitive psychology. According to Schmidt (1993), cognitivists regard prior knowledge as the determinate of the new information to be processed by individuals, and knowledge is structured in memory. The problem presented to students in PBL helps students to activate their prior knowledge and to restructure appropriate semantic networks in order to solve the problem. Based on the epistemology of constructivism, the problem in a PBL program works as a stimulus for authentic activity. Students are expected to reflect on their activities and evaluate their strength and weakness (Duffy and Cunningham, 1996). Duffy and Cunningham consider assessment to be ongoing, rather than just being an end-of-the-semester rating. Therefore, assessment must be in the learning context and can not be separated with the process of learning. They note that "the abilities to self-assess and to provide constructive feedback to team members are explicit learning goals, and this is not only an assessment process but also a learning process." Talking to the teacher's role in assessment, Brooks and Brooks (1993) suggest evaluating students through teaching, participating in interaction, and observing and watching student work with ideas and materials. The teacher can ask questions that challenge students to assess themselves.

The evaluation methods presented in this paper cover those from both cognitivism and constructivism. No matter what epistemology a PBL is based upon, it is important to provide a supportive learning environment so that students are safe to make mistakes and to fail (Bridge and Hallinger, 1995).

Categorization scheme of evaluation

Different taxonomies have been proposed by scholars to classify evaluation methods in PBL. Glasgow (1996) categorizes assessment strategies into three areas of content, process, and outcome. According to him, content assessment is concerned with knowledge students acquired. Process assessment focuses on students' abilities to apply knowledge in solving problems. Outcome assessment deals with the products created by students that may involve original knowledge or a new application of knowledge. Similar to Glasgow's taxonomy, Swanson, Case and Vlerten (1991) use process and outcome to classify evaluation methods. Their examples of process include communication skills in tutorial groups, acceptance of responsibility for learning, learning to learn, use of learning resources, and development of problem-solving skills, while they use outcome assessment to indirectly measure the quality of the learning process by testing the results of that process after it has been operating for a period of time. Barrow and Tamblyn (1980) also address the classification of process, content, and outcome. Bridge and Hallinger (1995) classify evaluation methods in terms of who structures the assessment and who judges the performance. According to this taxonomy, four evaluation types are described as the instructor-structured and student-judged evaluation, instructor-structured and instructor-judged evaluation, student-structured and instructor-judged evaluation, and student-structured and student-judged evaluation.

In describing the assessment methods I chose process-oriented and outcome-oriented approaches to classify them. The process in my categorization scheme refers to students' behaviors and the outcome to their products. According to Papham (1990), process and outcome can be replaced as behavior and product, and this two-part classification scheme takes care of all examinee responses. Unlike products, which can be subsequently measured, behaviors disappear once they occur. So we must make sure that the behavior is recorded. Popham emphasized the importance of evaluating students' behaviors and notes that "sometimes educators will wish to concentrate on the behaviors used by a student during the early stages of the student's creation of a product," that is, the process. On the other hand, outcome-oriented assessment techniques assess a student's products, such as essays or portfolios. In this study, I regard some product format evaluation tools, for example videotape, as process-oriented assessment tools because they are used to record the student's behavior. Students' behaviors include those in the evaluation process or in the learning process that are evaluated.

According to Reigeluth (1983), the three major components of a theory of instruction are methods, conditions, and outcomes. Methods are "the different ways to achieve different outcomes under different conditions". Conditions are defined as "factors that influence the effects of methods," while outcomes are "the various effects that provide a measure of the value of alternative methods under different conditions." In this section I would like to apply Reigeluth's CMO model to present the condition variables, the process-oriented, and the outcome-oriented assessment methods in a problem-based learning approach. Since a detailed description of learning outcomes is presented earlier in this paper, the intended outcomes of each assessment method will be mentioned shortly in this section.

Condition variables in student evaluation.

The condition variables of student assessment fall into three parts: environment / learner characteristics, subject content, and time constraints. Learner characteristics refer to the attribute each learner possesses, such as the student's prior experience (e.g. use of computers), cognition style, and psychosocial traits, which will influence the learner's learning and interpersonal skills. Environment variables mean the availability of resource materials,

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computer facilities, and classroom capacity. In addition, subject content, program goals, depth of problems selected in a PBL course (well-structured vs. ill-structured problems), and available time are important variables that will influence the selection of evaluation methods.

Process-oriented evaluation methods

1. **Tutor, peer ratings:** tutor and peer ratings are common assessment techniques that can be used to assess communication, group cooperation, effect, and self-directed learning skills (Swanson, Case, and Vleuten, 1991). Barrows (1988) describes one task of the tutor as educational diagnosis, in which he monitors the progress of each student in the group and recognizes any learning difficulties. Techniques of peer evaluation are based on the belief that group members are in a good position to evaluate each other during the learning process. In addition, peer evaluation provides a student with the sense of control over the behaviors of his group members before he is confident enough to enter and learn wholeheartedly in the group (Allen, Duch & Groh, 1996). The shortcoming of peer evaluation method is that little information is provided because raters can only give an overall impression of co-workers without precise ratings of distinct skills. The skills to be assessed are listening and communication skills, interpersonal skills, group cooperation, self-directed learning skills, and ownership.
2. **Self-evaluation:** self-evaluation refers to the learners' assessment of themselves, how they review their own work, knowledge, or skills to identify inadequacies (Barrows and Tamblyn, 1980). Wilkerson and Feletti (1989) suggest using PBL to encourage students to assess their own learning through discussion in small groups to compare their answers with those of others, to discover errors in thinking, and to hear correct solutions. Barrows (1988) also suggests students in a small group describing how they did in terms of reasoning through the problem, their self-directed learning skills, and support of the group process. Walton and Matthews (1989) note that as students develop the self-directed learning skills, their self-assessment and criticism should become automatic. Once students acquire the skills of reflection and deliberation, they will become more responsible for their own education. In terms of the evaluation tool, Barrow and Tamblyn present some examples to help students assess themselves as the self-assessment unit, review and comparison of criterion performance, peer review, and review with faculty. The skills to be assessed are self-directed learning skills, problem solving skills, and group-member skills.
3. **Unobtrusive measure:** Swanson, Case, and Vleuten (1991) list some usable tools that can be used to evaluate the student's learning process. They are library records of books and articles that were checked out, computer records of article searches, and students' logs or diaries reviewing their learning activities. This method is better for curriculum evaluation than student assessment because it's hard to standardize all the information that needs to be assessed. The skills to be assessed are skills to locate and use useful resources.
4. **Oral examination:** according to Barrows and Tamblyn (1980), the oral examination "has the advantage of establishing a dialogue or interaction between the student and the examiner." The examiner can explore the student's areas of strength and weakness regarding his knowledge and thinking ability. The examiner can also gain a sense about the student's self-evaluation, personality, and his reaction under pressure. However, low reliability and validity may be a problem due to personal biases. The classic example is the "Triple jump exercise" in which students first discuss possible problems and hypotheses of a given problem with the examiner, locate and review resources, and then discuss the solution of the problem with the oral examiner. This method is used at McMaster University to assess problem solving and self-directed learning (Norman, 1991). The skills to be assessed are problem-solving skills, self-directed learning skills, and knowledge of the content area.
5. **Observation of a patient interview and examination:** the student's interview of a real or simulated patient is observed by the teacher. The observation allows the teacher to estimate the student's abilities to choose appropriate questions, his interview, inquiry and physical examination skills, and use of time. The weaknesses of this method are non-standard criteria of student performance and the bias of examiners. In addition, patients vary in a wide range and cause uncontrolled variables.
6. **Patient problem simulations:** Barrows and Tamblyn (1980) discuss patient problem simulations as an evaluation method that is based on the simulation of the patient problem. Simulated situations are provided in several formats for students to react to and interact with. Students' behaviors are recorded or observed for evaluation. Examples of this are scenarios that deal with sequential management problems, portable patient problem packs, simulated patients, mechanical mannequins, and use of models.

(1) **Sequential management problems:** an opening statement about the patient is presented to a student so that he can to describe the possible problems of the patient and the actions to take next. Skills assessed include the perception and interpretation of data, problem formulation, generation of hypotheses, and inquiry strategies.

(2) **Portable patient problem pack:** using this method represents a patient problem in playing-card format that gives a student the opening picture of the patient's problem. The student can choose any actions in any sequence. After he chooses an action, he can get correct information by reading the back of the card. His inquiry path is recorded by the sequence of card he chooses. Skills assessed include cognitive process, data perception and interpretation, hypothesis generation, problem formulation, inquiry strategy, and diagnostic decision-making.

(3) **Simulated patients:** this method is the same as "observation of student interview and examination" mentioned before.

(4) **Mechanical mannequins:** the assessment is based on students' observation or evaluation of mechanical simulations of the human body or portions of the human body. It is an excellent way for complex medical skills to be learned at no risk to patients. Computers are used to simulate patient symptoms and to record the various actions of students. At the end of the exercise, the computer will print out the record of performance, time used, dosage of medicines, and other steps. Skills evaluated include the execution of complex skills in observation, physical examination, and medical intervention.

(5) **Models:** students manipulate and evaluate mock-ups of the various parts of the body represented with plastic, plaster, metal, and wood dummies. Motor skills are evaluated.

7. **Review of case record:** review of case record is a technique that belongs to both process-oriented and outcome-oriented assessment methods. Teachers directly score students' case records. Case reports and patient's reports are used as evaluation tools. According to Barrows and Tamblyn (1980), the case report provides information that cannot be evaluated during the encounter; the patient's report evaluates student's ability to communicate in writing. Audit record is another tool used to collect information about what a student really did in his work with patients. The skills to be assessed are the ability to recognize important data, interpret that data, formulate hypotheses, make decisions, write diagnoses, and give treatment (The last three skills are products).
8. **Authentic assessment:** Herman, Aschbacher, and Winters (1992) note the characteristics of authentic assessment as relevance and meaningfulness to students. It uses contextualized problems to evaluate students' complex skills. There is no single correct answer in the authentic assessment. Since students know public standards in advance and the evaluation focus on individual pacing and growth, it creates a fear free evaluation environment. Authentic assessment should be a part of the learning process, for Barrows (1994) regards authentic assessment as a natural component of authentic learning.
9. **Performance assessment:** according to Barrows and Myers (1993), a wide variety of performances that can be evaluated in a PBL program include oral presentations, written presentations, audiovisual presentations, dramatic presentations, other fine arts presentations, illustrations, graphs, mathematical analyses, and portfolios. Students demonstrate their knowledge as they report their thinking and problem-solving process. The skills to be assessed are creativity and communication skills.

Outcome-oriented evaluation methods

1. **Review of case record:** see assessment method number 7 in the process-oriented evaluation methods.
2. **Student-judged evaluation:** in Bridge and Hallinger's (1995) book, they present several evaluation methods applied in a project-based curriculum. The five student-judged evaluation techniques are integrative essay, protocols, models or examples, knowledge review exercise, and probe questions.
    (1) **Integrative essay:** Bridges and Hallinger describe a problem-based curriculum for which the basic unit of instruction is a project and students use class time to meet in the project teams. Students prepare an integrative essay following each project. The structures of this integrative essay are based on two procedures: students discuss what they have learned and how they might use the knowledge; a list of questions is given for the students to choose and discuss.
    (2) **Protocols:** the elements in a protocol include instructions, guidelines, or checklists for students to guide their performance. In the example mentioned by the authors, students use protocols to judge their memos that are written during the learning process.
    (3) **Models or examples:** students produce products in the project-based curriculum. Models or examples are instances of products provided by teachers for students to contrast with their own products for self-evaluation.
    (4) **Knowledge-review exercises:** knowledge-review exercises are distributed at the beginning of each project. Students may use them as pretests or posttests or both.
    (5) **Probe questions:** the skills to be assessed are. A set of key questions is given to students at the conclusion of some projects that stimulate their thinking about their final products or performances.
3. **Multiple-choice examinations:** this format has been developed into a sophisticated method to assess recall of content knowledge, intellectual skills, or attitudinal dispositions. It has the advantage of presenting a large number of questions, which can be answered by students in a short time. However, Swanson, Case, and Vleuten (1991) claim that this method is often rejected in a PBL program because it can only assess factual knowledge. This format is argued by some educators to provide cues to the examinees and leads to suggestions of right answers.
4. **Short-answer or word-completion examinations:** this method is particularly suitable for measuring simple types of learning outcomes, like recall of factual information. It has the advantage of not cueing the student to the right answer. But it does not evaluate inquiry strategies or interpersonal skills.

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5. **Essay examinations:** according to Swanson, Case, and Vleuten (1991), this format can provide an in-depth assessment of problem-solving skills and encourage students to integrate their insight into a systematic framework. In addition, students' creativity and the abilities of organizing and expressing ideas can be evaluated. The essay question can be used to ask students to justify their decisions or explain relevant underlying principles. With good design of exam questions, this method can evaluate students' abilities to use knowledge in solving important problems. It can measure complex as well as simple types of learning outcomes. But it has the problem of poor generalizability of scores, which its reliability somewhat problematic.
6. **Patient problem simulations**
   (1) **Audiovisual examination:** there are a variety of ways that audiovisual media are used in place of clinical skill exams. It can measure students' abilities to make observations and interpret data but it cannot be used to evaluate other important clinical competencies, such as inquiry strategies and interpersonal skills (Barrows & Tamblyn, 1980).
   (2) **Computer-based clinical simulations:** in this simulation, the student is presented with an "opening scenario" that provides a description of a patient problem and then is given a set of options to choose from (Swanson, Case, & Vleuten, 1991). Additional information is gathered when the student proceeds through a series of scenes. The computer challenges the student's data perception and interpretation skills, the ability to intervene with a patient problem, and inquiry strategy.
7. **Portfolio assessment:** Herman, Aschbacher, and Winters (1992) describe recent trends in assessment and suggest using portfolio review as the basis for assessment by the teacher, students, and parents. They define portfolios as "collections of student work that are reviewed against criteria in order to judge an individual student or a program." The types of student works could be essays, videotapes, art, journal entries, and so on. In order to evaluate students using portfolio assessment, the teacher should define the assessment purpose, set methods for determining what to include in the portfolio by whom and when, and define the criteria for sample selection and judgment. Two skills in the example proposed by the authors are problem-solving and communication skills.

Conclusion

By reviewing articles in student assessment, one notices that assessment methods have changed, with their underpinning epistemology shifting from behaviorism to cognitivism to constructivism. There are more emphases on the importance of self-reflection and assessment in the learning context in recent years. Different evaluation methods are applied based on these epistemologies to better capture significant and enduring learning outcomes. Many evaluation methods described in this paper are applied in medical schools to assess students' clinical abilities. On the other hand, some techniques are used to evaluate students' problem-solving skills and various competencies in different fields. Techniques used for process-oriented evaluation have beneficial effects on student learning, while outcome-evaluation techniques have the advantages of ease of scoring and conducting. When making decisions in choosing appropriate evaluation methods, it is important to take the condition variables and desired outcome variables into consideration.

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